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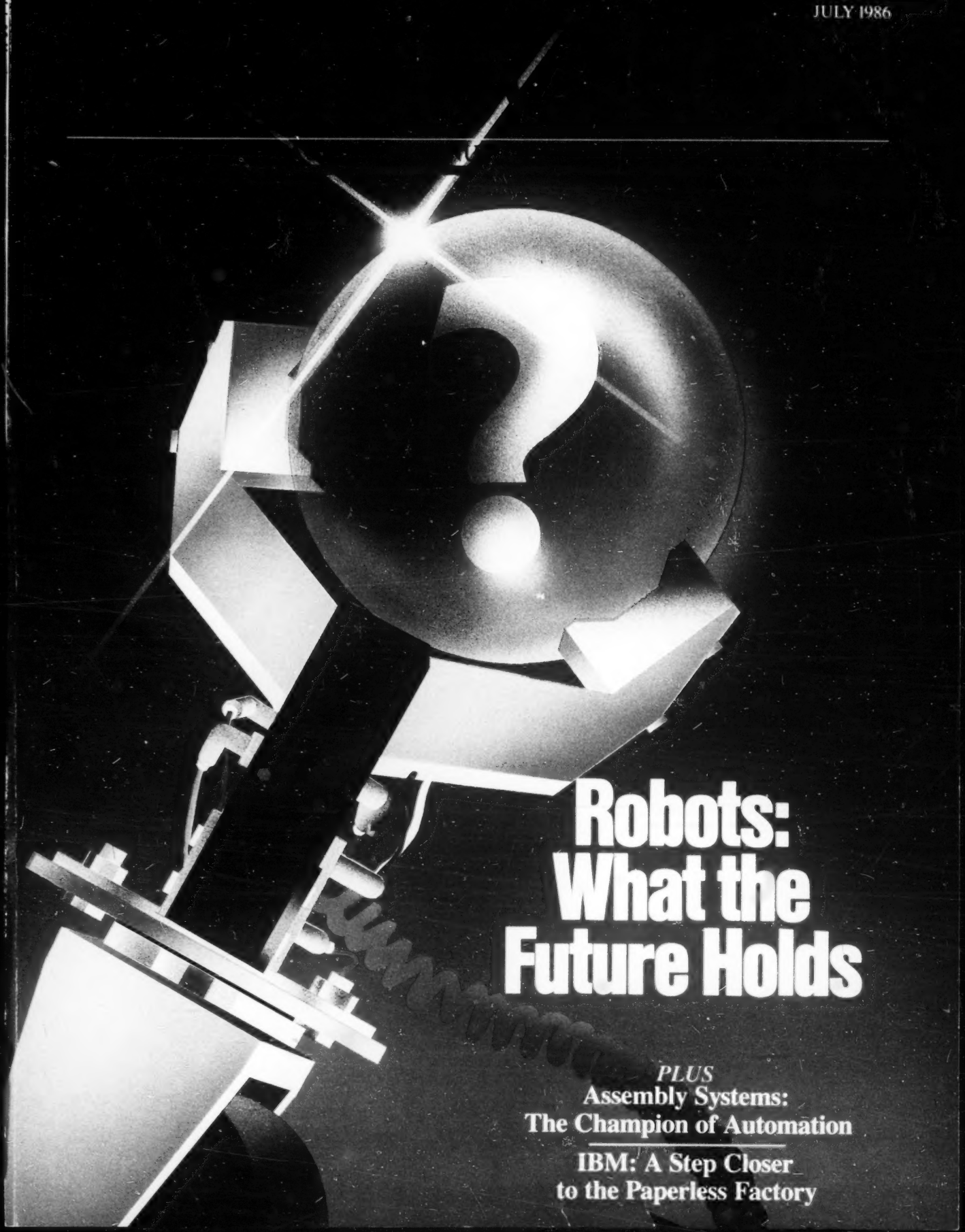

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PLUS

Assembly Systems: The Champion of Automation

IBM: A Step Closer to the Paperless Factory

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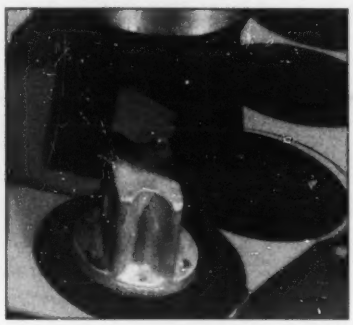

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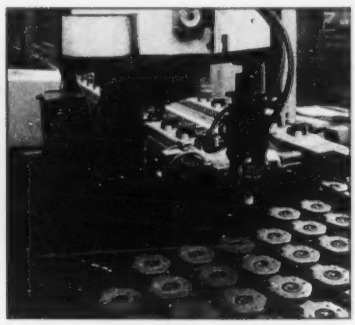

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it three years ago, at least 25 pct of the then-existing U.S. machine tool companies have either gone out of business, have been bought up by other interests, or have moved their operations offshore. The President's response should help stem this precipitous deterioration and thereby strengthen the national security." Mr. Gray said.

"Although the last few years have been especially trying for those companies that design and build machine tools, we have not been idle as the Administration studied the case. American builders recognize that they hold the key to their own future.

"For an industry that has not made any money since 1982, their commitment to research and development has been admirable. As a result, 75 pct of today's orders are for machine tools that embody technology not available in 1980.

"Moreover, the industry and key users are today working to establish a National Center for Manufacturing Sciences to conduct generic research and development.

"The recovery of our industry has been and will continue to be impeded by the fact that President Reagan was prevented by certain members of his own staff from even considering our petition for over two years.

"Those staff members, for reasons known only to themselves, refused to allow the recommendations of the Secretaries of Commerce and Defense on our petition to reach the President. Their inaction contributed significantly to the weakening of the very national security interests that they are charged with protecting.

"We believe that, as Congress develops comprehensive trade legislation this year, it ought to impose a deadline on the presidential decision-making process as it applies to Section 232 (National Security Clause) decisions, to prevent those involved in the process from causing similar damage to America's national security interests in the future.

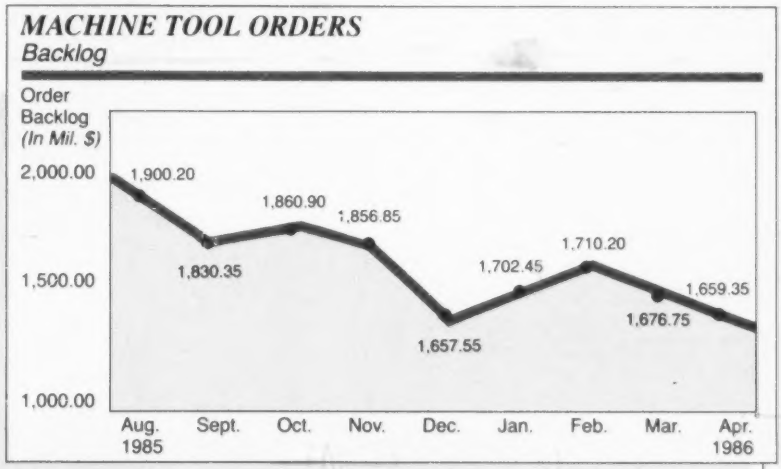
"We in the machine tool industry are proud of our historic role in providing the industrial muscle for America's national security and industrial development. We see the President's decision as an opportunity to build upon our record of service to the nation."

After a year's internal study of the problem, the machine tool industry's petition was initiated by NMTBA in March 1983 under Section 232, the National Security Clause, of the Trade Act of 1962. This requires the president to adjust imports of vital defense-related items if those imports threaten the national security.

Machine tool imports in 1985 accounted for about 41 pct of the value of the domestic market, up from 34 pct in 1983 when NMTBA filed its 232 petition.

Net new orders for American-made machine tools have declined from $4.8 billion in 1980 to $2.5 billion in 1985.

"We are delighted that the President has finally recognized how vital the machine tool industry is to our defense efforts."



Machine Tool Orders Down in April

New machine tool orders for April fell to $193.45 million, down to 9.9 pct from the $214.60 million posted in March, according to the National Machine Tool Builders' Association (NMTBA).

Orders for metal cutting machinery fell 14.8 pct to $136.25 million from $159.90 million. Metal forming orders rose 4.6 pct to $57.20 million from 54.70 million.

Comparing April 1986 to April 1985, metal cutting orders rose 11.6 pct while metal forming orders fell 6.8 pct, resulting in a net order gain of 5.4 pct over the same month a year ago. However, year-to-date figures for 1986 compared to last year showed an across-the-board drop, with metal cutting down 7.8 pct and metal forming down 19.8 pct, resulting in a combined loss of 11.2 pct.

Total cutting and forming shipments fell by 15.6 pct in April, dropping to $210.10. April metal cutting shipments fell to $152.90 million, a 10.9 pct drop. Metal forming shipments fell by 26.0 pct, down to $57.20 million for the month. Year-to-date combined shipments showed a 15.1 pct rise over the same term a year ago, with metal cutting up 17.3 pct and metal forming up 10.9 pct.

Metal cutting backlogs were down to $1.3 million, a drop of $16 million for the month. The metal forming backlog remained the same as in March at $365 million. The April combined metal cutting and metal forming backlog figure has dropped to $1.6 million.

Automakers Increase Use Of P/M

The U.S. automotive industry could increase its usage of powder metallurgy (P/M) parts used in an average car to 40 pounds per car in the not to distant future, according to Kempton H. Roll, executive director of the Metal Powder Industries Federation (MPIF).

The automotive market accounts for 70 pct of the output of P/M parts in North America.

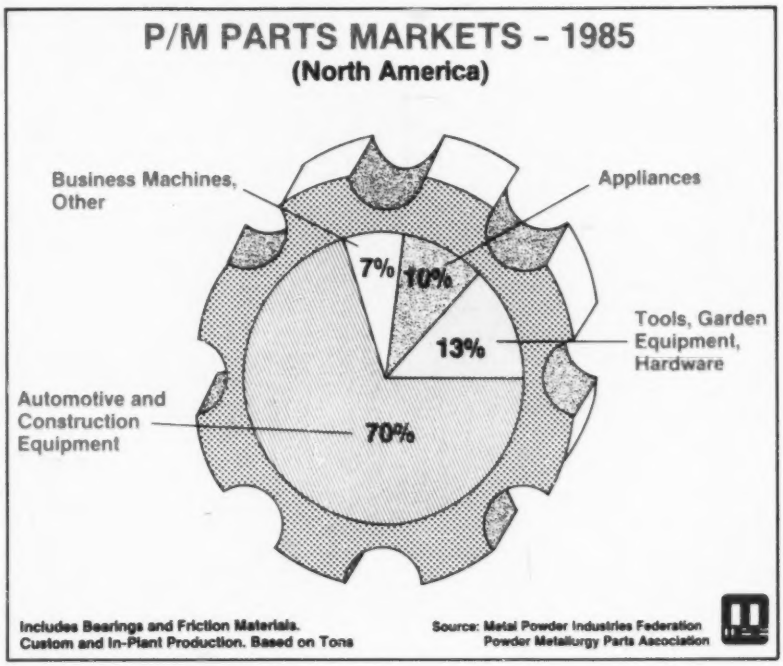
As an example of P/M inroads in cars, the Federation recently gave awards for a high strength, P/M alloy steel-forged internal ring gear, used in GM truck transmissions and a 4600 forged-steel P/M transmission race used in the new Ford Sable and Taurus model cars. The internal ring has a surface tensile strength of 300,000 psi and a tensile strength of 220,000 psi in its core. The Ford automatic transmission race was designed as a P/M forging to obtain improved fatigue.

P/M steel forged connecting rods are expected to be used in Ford and GM cars in the 1987 model years.

Markets for P/M parts in appliances are up 10 pct due to increased housing starts. The use of P/M parts in lawnmowers and tractors, power tools, recreational equipment and hardware is growing and represents about 13 pct of the industry's output.

Total metal powder shipments in 1985 declined about 10.5 pct to 269,220 tons. Mr. Roll attributes this to both inventory adjustments and the impact of foreign competition.

–Eastern region reported by Tom Halligan/Philadelphia



MIDWEST

Chrysler Invests $866M in St. Louis Plants

Chrysler will invest $886-million at its two assembly plants in St. Louis, Mo., which produce the minivan and is slated to produce a new sporty front-wheel-drive mid-specialty car.

Currently the Windsor, Ontario plant is the only facility building the Plymouth Voyager and Dodge Caravan minivans. Since their introduction in 1984, they have been "sold out"—last year the minivans took 51 pct market share. Chrysler has been seeking a second source for over a year and will spend $475-million to make the St. Louis II Assembly Plant that second source. Production is expected to begin next March.

Five new buildings, 500,000 sq. ft. will be added to the facility for minivan production. In addition, state-of-the-art technology will be installed—the number of robots will increase from five to 125 and the number of computers will rise to 847 from 54.

However, Chrysler must now find a new source of production for its large rear-wheel-drive models—the Chrysler Fifth Avenue, Dodge Diplomat and Plymouth Gran Fury—currently assembled at St. Louis II.

At the recent American Motors Corp. shareholders meeting, president and chief executive officer Joseph Cappy said that preliminary discussions were underway with Chrysler to produce those vehicles in the Kenosha, Wisc. AMC facility. However, Chrysler has an underutilized plant in Brampton, Ontario which could be retooled for M-body production.

The St. Louis I plant is slated for a $391-million face-lift to gear up for production of a "brand new, super sporty mid-specialty car" to be introduced in October. The plant will be expanded by more than 130,000 sq. ft. and technology will be upgraded to 21st century standards—robots increasing to 191 from 70; machine welders to 94 from 82; computerized weld controls more than doubling to 376 from 170.

The new model, a two-door hardtop and convertible version of the LeBaron series, will be integrated into production with the Dodge Daytona and Chrysler Laser currently assembled at the St. Louis I line.

Computers in the Board Room– Look But Don't Touch

Senior managers are more likely to review the printout than use the computer.

MORE THAN HALF THE TOP EXECUTIVES of America's largest corporations never use a computer, but more than 64 pct of these executives believe computers "help managers do their job better." The chief executive and chief operating officers of the Fortune 500 companies—821 people in all—surveyed by Kepner-Tregoe, Inc., the Princeton based specialists in human resource consulting and software for managers, were asked a series of questions about current and future computer use in their organizations.

Of the 92 executives who responded, 70.6 pct of them do not have a computer terminal in their office. Only 27 pct do have a terminal within arm's reach.

When asked if they "personally use a computer," 18.5 pct said they use a computer "often," 27 pct use it "sometimes," and 52.2 pct use it "never."

The CEO's and COO's were also asked if they personally review computer printouts. Of the total, 13 pct "never" do; 49 pct review them "sometimes" and 28 pct said "often."

Thus, America's most senior managers are more likely to review computer printouts than to use a computer. This is also reflected in our finding that other top managers, below the CEO-COO level, are more likely to use computers than the CEO's and COO's themselves.

Question: *What percentage of your top management team uses computers?*

Percent of Usage Reported	Percent Responding
0-25	54.9
26-50	24.2
51-75	8.8
76-100	12.1

When the senior executives were asked what they "most frequently use the computer to accomplish," the overwhelming choice was financial analysis. A distant second was word processing. Only one respondent said "planning."

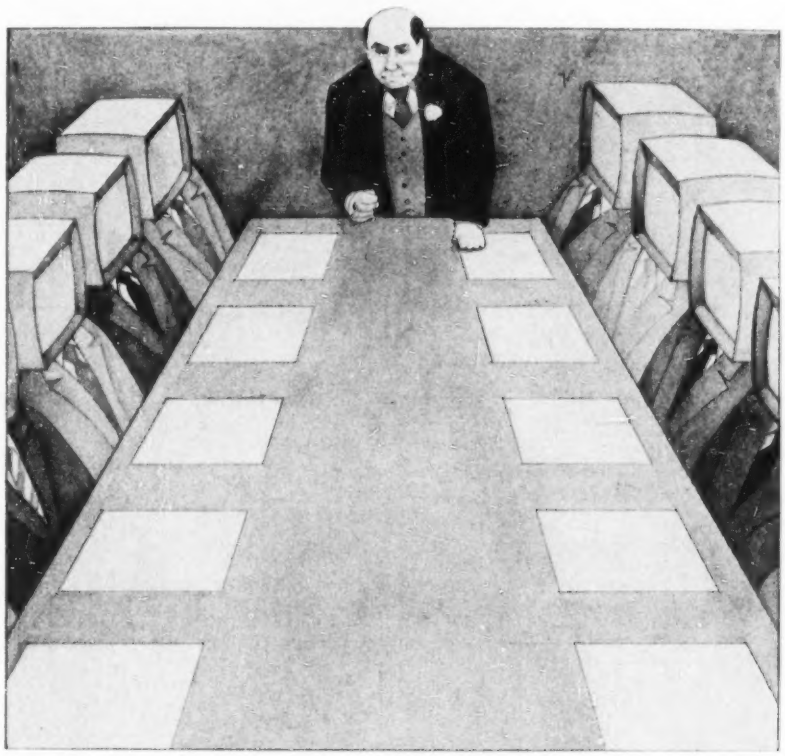


Illustration by Steven R. Cusano

Question: *If you do use a computer, what do you most frequently use the computer to accomplish?*

Answers	Percent Responding
Financial analysis	26.1
Word Processing	7.6
Telecommunication	3.3
Scheduling/calendar	3.3
Market trend analysis	3.3
Margin ratios	3.3
"What if" scenarios	2.2

The senior executives were also asked to identify both the greatest threat and the greatest opportunity posed by the computer. The greatest opportunity, identified by 22.8 pct of respondents, is time saving. The top two threats were a tendency to bog managers down with unnecessary data, mentioned by 12 pct, and the computer as a substitute for thinking which 10.9 pct noted. However, a greater number, 13 pct, said there is no threat at all from using computers.

Question: *What is the greatest* **opportunity** *posed by the computer for your business organization?*

Responses	Percent Responding
Time saved/timely data retrieval	22.8
Production, manufacturing control	11.9
Improved decision making	9.8
Greater accuracy and availability of data	9.8
CAD/CAM modeling	8.7
Increased efficiency/ better organization	7.6
Improved customer service	5.4
Better communication	4.3
Enhance personal productivity	3.3
Manage complex data	3.3
Gain competitive advantage	3.3
Reduce costs	2.2

Question: *What is the biggest* **threat** *posed by the computer for your business organization?*

Responses	Percent Responding
No threat seen	13

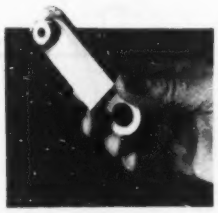
Computers have a long way to go to reach their full potential to improve the way we manage.

Excess or unnecessary data	12	Poor management of the computer itself	3.2
Substitute for thinking	10.9	Digression from work assignments	3.2
High cost	8.9		
Security problems	4.3		
Inaccurate data	3.2		

The overall reactions to current and future computer use by these CEO's and COO's was positive, but the negative comments surface major hurdles separating computers from increased efficiency.One CEO said, when asked if computers help managers do their jobs better, "No. They are tools for people who do tasks—not managers." (This CEO also indicated that no one in top management in his or her organization uses a computer.) Another response to the same question was, "Middle managers, yes—top management, not yet! Systems capability not available to make computers more effective." A third responded, "Executives are paid too much to develop computer skills at their current level. Executives are being paid to analyze and implement." And a fourth, emphasizing how computers can contribute positively, commented that computers provide an opportunity for "Enhancing personal productivity, just as the telephone did." The implication in all of these remarks is that computers have a long way to go to reach their full potential to improve the way we manage.

Other foreboding views of computers in executive suites include several executives who cautioned against inaccurate data contained in the computer. Still others, typified by one CEO's comment, cautioned against "dehumanization of decision making." Another CEO warned that computers "take judgment out of decisions." "Loss of personal touch with raw data, loss of personal dexterity," was one respondent's somber view. Yet another warned against "Becoming too data bound! There will always be a place for intuitive and creative judgment which can cut through endless analysis." A fear of "conformity—consensus thinking in management" was expressed by a senior exeuctive. In a similar vein, one COO fears "centralization—don't want it."

One of the most curious responses was by a chairman of the board who said computers help managers do their job better, but no one in senior management in his or her company uses a computer! P



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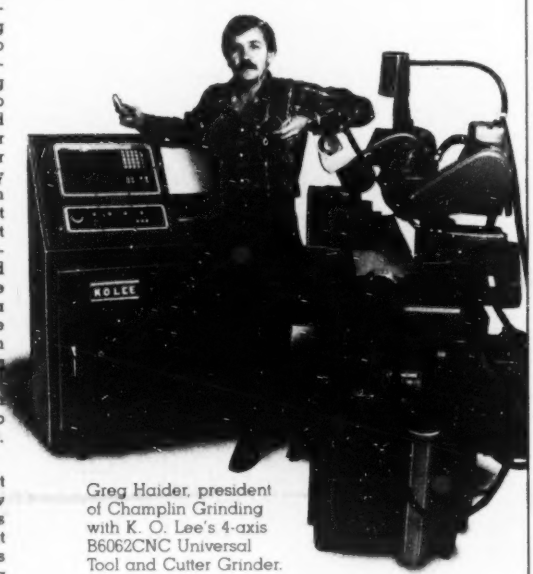

Greg Haider, president of Champlin Grinding with K. O. Lee's 4-axis B6062CNC Universal Tool and Cutter Grinder.

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Robots: What the

Today, 25 years following the invention, the industry finds itself in a state of transition.

By Thomas M. Halligan
News Editor

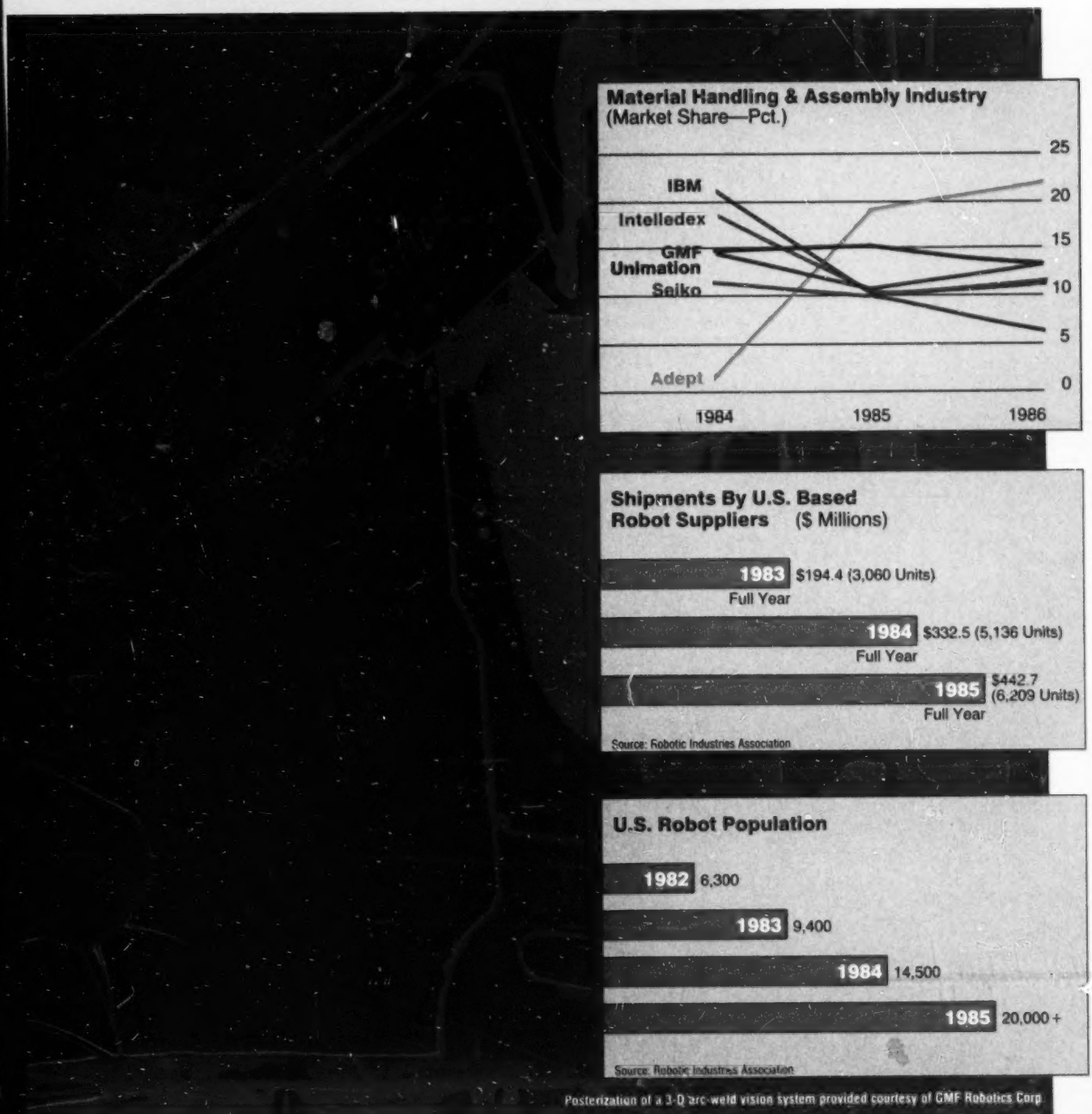
IF YOU LISTENED VERY CAREFULLY during the conferences at the recent Robots 10 exposition, thoroughly read the manufacturers' brochures and the conference proceedings, questioned sales personnel on the display floor, and again during the evening receptions, you would definitely come away confused about the present—and future—state of the robotics industry. And justly so.

Has it leveled-off? Some analysts contend it has. Is it in transition? That's what some manufacturers stressed. Are new markets being sought to supplement the fickle auto industry? Positively, said others. Will vision systems and off-line programming be incorporated into every robot produced in the future? Will there only be a handful of manufacturers within 10 or maybe 5 years? Will prices come down? Go up? What about integration? Well, you get the picture.

Probably no other piece of industrial machinery in the past 25 years has received as much scrutiny as the industrial robot. This is in large part due to the robot being extolled as a replacement for the human factory worker, coupled with the robot's personification depicted in futuristic novels, films and television shows.

But today, some 25 years after Unimation founder Joseph Engelberger constructed the first industrial robot for General Motors, one point is clear: The

Future Holds



Posterization of a 3-D arc-weld vision system provided courtesy of GMF Robotics Corp.

Percentage Distribution of Robot Sales in the U.S., by Robot Application

	1985	1990	1995
Machine tending	16%	15%	15%
Material transfer (excl. machine tending)	16	15	15
Spot welding	26	15	10
Arc welding	10	10	9
Spray painting/coating	10	10	7
Processing*	5	7	7
Electronics assembly	6	12	14
Other assembly	5	8	12
Inspection	5	7	10
Other	1	1	1
	100%	100%	100%

*Includes such applications as routing, drilling, grinding, etc.

Forecast of Dollar Sales of Robots in the U.S., by Application

	1985		1990		1995	
	Unit Sales	Total $ (mil.)	Unit Sales	Total $ (mil.)	Unit Sales	Total $ (mil.)
Machine Tending	800	28.0	1,650	61.1	2,250	89.8
Material transfer	800	28.8	1,650	62.7	2,250	78.8
Spot welding	1,300	78.0	1,650	95.7	1,500	75.0
Arc welding	500	30.0	1,100	66.0	1,350	78.3
Spray painting	500	30.0	1,100	66.0	1,050	63.0
Processing	250	11.3	770	38.5	1,050	62.0
Electronics assembly	300	10.5	1,320	52.8	2,100	66.4
Other assembly	250	8.8	880	30.8	1,800	63.0
Inspection	250	13.0	770	38.5	1,500	75.0
Other	50	2.0	110	4.2	150	6.0
Totals	5,000	$240.4	11,000	$516.3	15,000	$637.3

Percentage Distribution of Robot Sales in the U.S., by Industry

	1985	1990	1995
Agriculture	1%	1%	1%
Mining and extractive	1	2	2
Construction	0	1	1
Electricity generation	1	1	1
Consumer non-durables	2	5	5
Non-metal primary commodities	2	4	5
Primary metals	3	4	5
Non-metal fabricated commodities	5	6	6
Fabricated metal products	10	8	8
Machinery	8	10	11
Electronics/precision equipment	8	10	16
Automotive	51	38	26
Aerospace	6	6	8
Other transport equipment	2	3	4
	100%*	100%*	100%*

*May not total 100% due to rounding.

*Reprinted courtesy of the Society of Manufacturing Engineers and the University of Michigan from Industrial Robots Forecasts and Trends, copyright 1986.

robotic industry is, indeed, in a state of transition. But this transition stage is one that will catapult the industry into the next decade armed with new generation sophistication, diversification and applications. And too, the robotics industry will penetrate a wide variety of new industries including electronics, the hazardous waste industry, pharmaceuticals, precision equipment, semiconductors, the garment industry and medical applications. Of course, metal-working manufacturing will see the greatest spread of robotics in the future.

Consider the findings excerpted from a recent study conducted by the Society of Manufacturing Engineers in conjunction with the University of Michigan, entitled, Industrial Robots, Forecasts and Trends:

- Actual numbers of robots purchased in the U.S. are expected to increase throughout the decade in all manufacturing classifications. The current leading consumer, the automotive industry, will account for a shrinking share of expanding total sales (51 pct now, 26 pct in 1995), as other industries, particularly electronics and precision equipment producers (8 pct now, 16 pct in 1995) accelerate their pace of robot purchases.
- Industrial robots are forecast to change in appearance, improve in accuracy, and become available in abundant variety. By 1995, for example, 15 pct will have two or more arms, 11 pct will be mounted on ceilings or walls; 21 pct will move along a track; some computer control devices (micro, mini, or mainframe) will direct the movements of 90 pct of all robots; and certain classes of robots will be accurate to ±.0005 inches per second.
- Half of all robots that are controlled by computers are expected to be programmed off-line by 1995; some 40 pct will be debugged by CAD simulation. The odds of a standardized off-line robot programming language being in use during this period was rated 25 pct by those surveyed by the SME.
- Robot leasing and time sharing programming services are projected to

develop into thriving commercial sectors; 15 pct of all robot units will be leased and a similar share programmed by time-sharing in 1995.

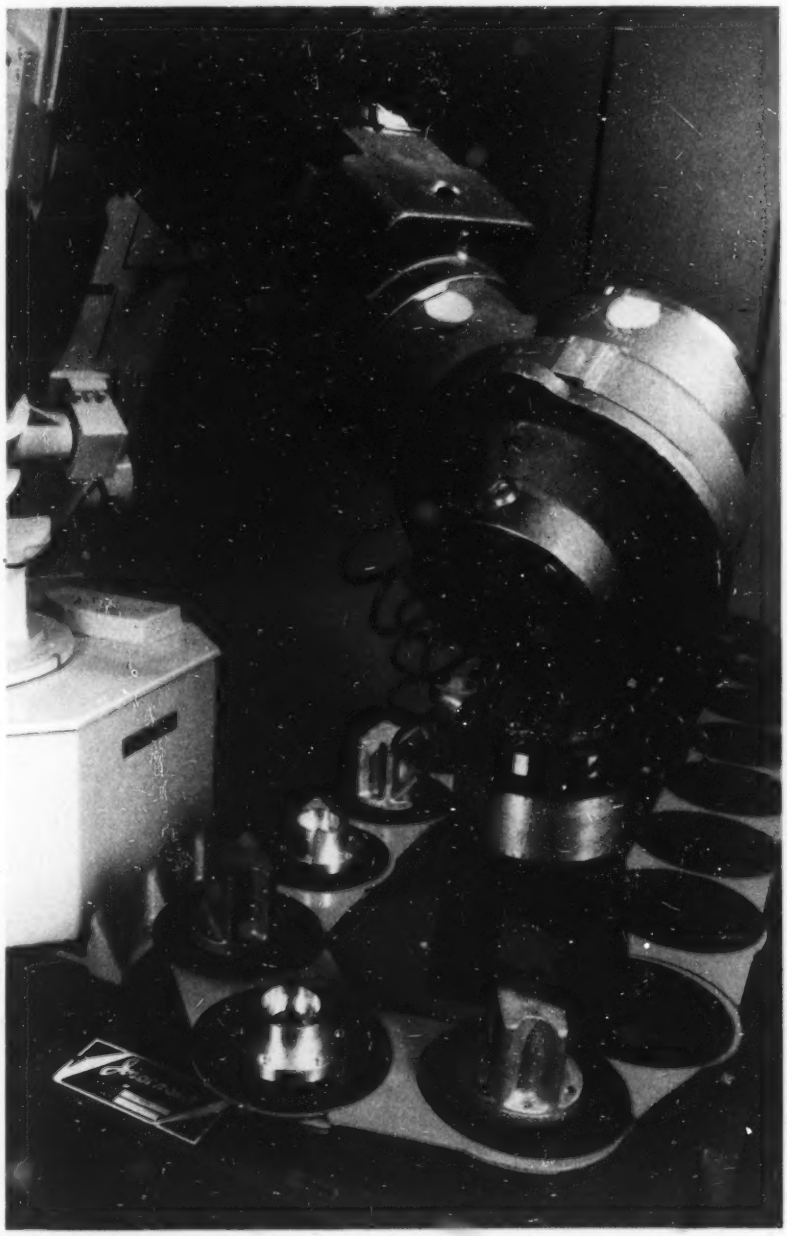
• Sensory devices will be utilized by 60 pct of all robots by 1995, according to the forecast. They will be most plentiful on robots devoted to inspection, assembly, and welding tasks. Among robots with some form of sensing capabilities, 25 pct will have machine vision, 25 pct tactile sensors, another 25 pct some kind of sensor (e.g., range proxmity), and the balance will be equipped with two or more sensor types.

• The U.S. manufacturer of robots is expected to create more than 44,500 jobs by 1995. Some 3,000 workers will be employed by robot producers, 4,500 in supplier industries, another 25,000 will perform maintenance in robotized facilities, and about 12,000 programmers will create and maintain robot software.

Overall, the industry as a whole should see an annual growth rate of between 20 and 38 pct, according to projections garnered from various manufacturers, industry analysts and robotic associations. Domestic sales are expected to reach close to the $5 billion mark by 1995. And by the end of the century approximately 165,000 robots will have been installed in the U.S. At present, there are about 20,000 working robots in the U.S. equalling $440 million in sales.

Optimistic? Yes, especially if you consider the present state of the robotics industry. Certainly there are problems. Recent accounts of horror stories by end-users, amplified in the general news media, have caused some manufacturers to cancel robot orders and rethink overall automation plans.

"The problem," remarked Lester V. Ottinger, president, Advanced Manufacturing Systems, "is that we're doing a pretty good job producing sophisticated robots, but we lack in the final implementation. We're not doing a good job launching these things. Automating a factory is like a symphony orchestra. Each section—the horns, strings and percussion, is good by itself, but if they haven't practiced together, they can't make music. We're not using our tools in concert. People are looking for some giant solution to solve the mystery of trying to bring the technologies together...It's common sense...we just haven't practiced enough yet," he said.



A Cincinnati Milacron T3 786 robot can handle a 200-pound payload but is flexible enough to give 238 degrees of pitch and yaw motion, and 900 degrees of roll motion.

"It's not the robot or the equipment that's really expensive, it's the way manufacturers have to change to incorporate the technology," added Jerry Saveriano, president of Saveriano Associates, an automation consulting firm, who has devoted the past 11 years

Next Generation Robots

There are 20,000 working robots in the United States today. By 1995 projections call for approximately 500,000 robots to be at work in a vast array of industries, performing exotic applications.

What will these next generation robots be like? What materials will they be made from? What applications will they perform? And how much will they cost?

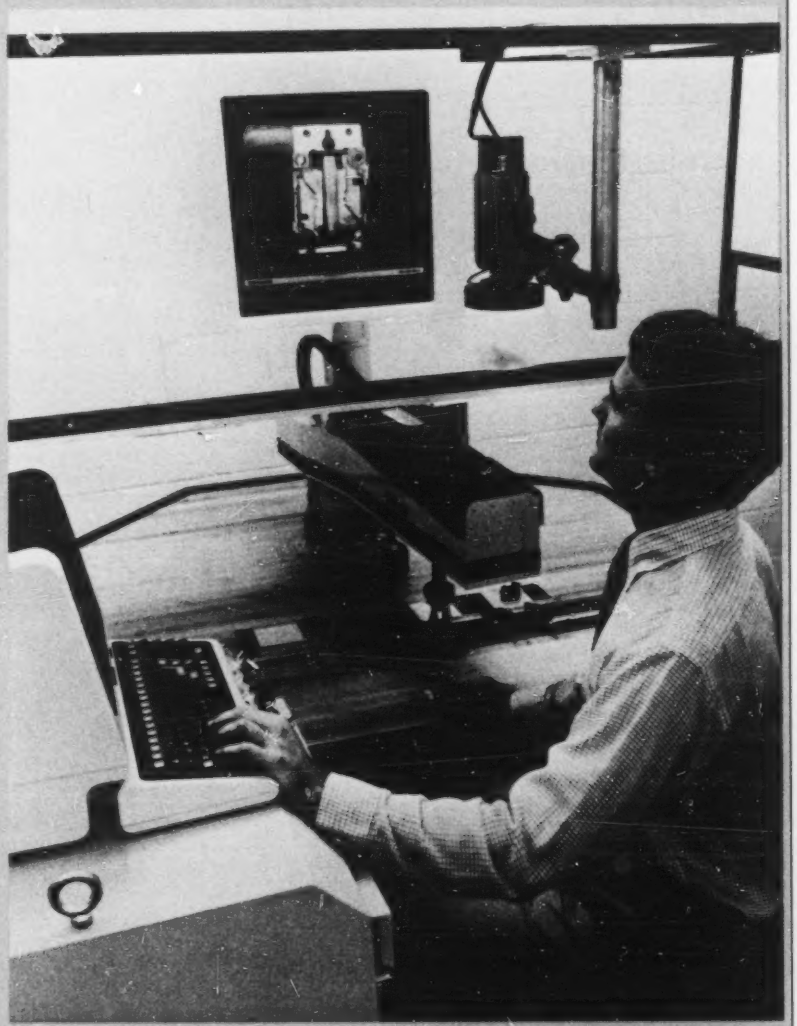
From interviews with industry leaders, and information gathered from reports and forecasts, the following is an overview of the next generation of robots.

Almost everyone in the robotics industry agrees that there will be an increasing use of vision and sensor systems in the next generation of robots. One analyst put it this way, "A robot in the future won't be a robot if it doesn't have vision."

"As we look down the way," said Eric Mittelstadt, president and CEO, GMF Robotics, "there will be the development of smarter robot mechanism that have built-in or integrated intelligence capabilities: vision and sensors and mobility and logic...a growing number of products added onto the robot mechanism and its immediate controls, such as off-line programming, CIM, vision and other intelligence forms."

Ken Goodwin, deputy chief, robotics division, National Bureau of Standards forsees an increase in mobile robots in the future. Mr. Goodwin sees such robots being used in the hazardous waste and mining industries; industries dealing with radiation, and nuclear waste disposal, and an increasing use of robots for painting and spraying applications. The technology creating mobile robots will filter down from the military, in which "battlefield robotics" is now an area of research and development, he said.

According to *Industrial Robots, a summary and forecast*, compiled by Tech Tran Consultants, Inc., future robot design will see specific changes in weight, strength speed, accuracy, flexibility, standardization, and lower cost.



Tactile, vision and other sensory technology has expanded the use of robots in industry. The operator here is programming a Unimate 900 small assembly robot with a vision system. The robot control is under the keyboard at left.

The report indicated that lighter materials such as plastics and composites will be used for robot structures and components; robots will become smaller but their relative payload capacity to weight will increase; robots will be faster due to direct drive motors and better control systems; and they will be more accurate, have flexible grippers and, most importantly, become less expensive as their electronic elements continue to decline, and production volumes increase.

The report also projected robots increasing in emerging applications such as maintenance and security, agriculture, forestry, mining, construction and a variety of service industries.

View from Europe

Technology Keeps Robot Industry Moving

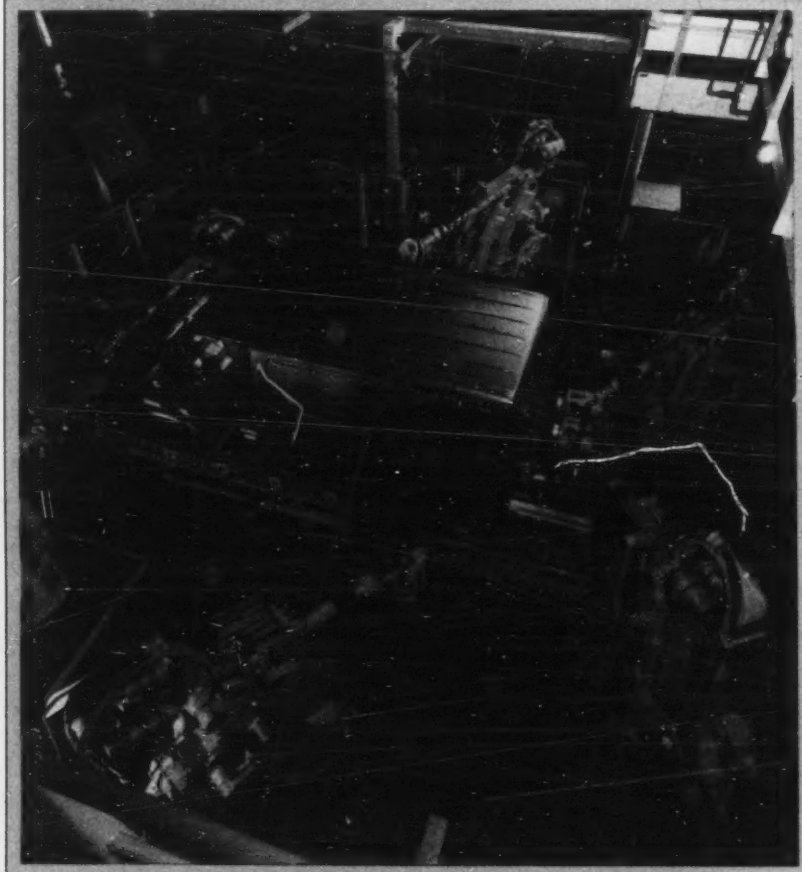
By Peter Mullins
European Editor

According to Bjorn Weichbrodt, chief executive of ASEA Robotics in Sweden, the international market for industrial robots is expanding at 25 pct a year. The annual growth rate of his own company is 50 pct. ASEA has recently built a new robot manufacturing plant in Sweden and has started production in the U.S., France, Spain and even Japan.

The other major independent robot maker in Europe is the West German company, Kuka (Keller und Knappich Augsburg). Kuka is part of a large group which includes controls systems and welding equipment companies.

Volkswagen, Fiat and Renault all make their own robots, but have so far installed relatively few outside their own factories.

The greater bulk of the industrial robots installed to date are in the motor industry. The majority of these are used for spot welding. However, the spot welding market is showing signs of slowing down as carmakers' welding lines approach saturation and automatic assembly is providing a growing market. Robotic arc welding has been expanding over the last few years, but has not developed as fast as anticipated.



Kuka robots welding the body of a Transit van at Ford's Southampton plant. More than a hundred such robots are employed at the plant making literally scores of derivatives of the short and long wheelbase vans.

"There is still a big potential for robotic arc welding, but seam tracking devices and sophisticated sensors have not come along as fast as they should and are holding up development," noted Derek Wainwright, managing director of Kuka Welding Systems and Robot Ltd, Theale, England. "There is also a growing market outside the motor industry among makers of volume domestic proudcts like lawn mowers and garden tools."

The comparatively recent introduction of gantry-type robots indicates a trend towards denser robot installations, particularly on car-body lines. ASEA has pointed out that putting two conventional robots on either side of a line and hanging one over a work station saves space and also peripheral equipment.

An excellent example of this occurs on a brand-new production line in Holland where the small Volvo 480 ES is being made. (Incidentally, this car is being introduced in turbo form to the U.S. market in about year). On one work station, the floorpan of the car is welded on either side by two ASEA IRB90 robots while a Kuka IR 200/500 gantry robot carries out a weld in the middle of the component.

The 200/500 robot has been designed for very high pressing forces—up to a ton—mainly for single-sided welding operations where it is impossible for welding pincers to operate. In this case, the robot-held welding electrode is pressed against backing electrodes under the floorpan.

A very unusual approach to keep down the number of robots necessary in a given installation is the one adopted by the Italian robot specialist, Bisiach and Carru SpA of Turin. The Tauro

system as it is called (the acronym comes from the Italian equivalent of robotised universal automatic transfer) comprises two types of robots carriers: the first a gantry capable of taking one to three robots; and the other a smaller single carrier. Both are rail mounted and programmable.

These take the robots to the work, which may be a whole series of different models of car or truck...or tractors for that matter. A system of interchangeable welding guns gives great flexibility and avoids the necessity for having a separate robot for each weld gun. The system is similar to a machining center with tool magazine.

In a typical installation, the single carriers (each with a three-gun magazine) will move down the line working on either side of the workpiece. The gantry type (with an eight-gun magazine) will straddle the line.

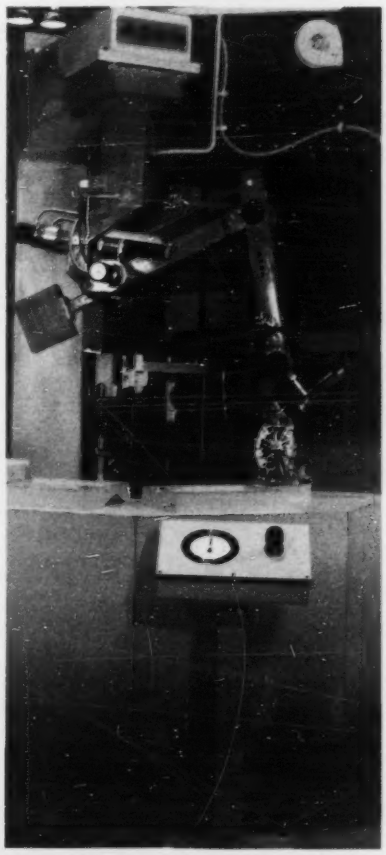
A recent example of the Tauro system at work is at Steyr-Daimler-Puch in Austria on a line making 6-wheeled cross-country vehicles. An interesting variation here is that the robot changes the weld gun for a manipulator at a certain point in the line and thus is able to carry out a certain amount of subassembly before welding.

In general, such an arrangement uses far fewer robots and is much more flexible than a conventional robot system.

Bisiach and Carru has pioneered a number of innovative ideas in robot welding. One is a double head, combining a weld gun with a manipulative pick-up; another is a double-tip gun with a programmable pitch.

It would appear that all robot specialist companies are trying to get more work out of their robot installations to amortise the high costs more quickly.

Robot installations are also becoming denser to save space. The gap between welding and automatic assembly is beginning to be bridged as robots combine the two functions.



ASEA Robotics' closed-loop adhesive /sealant dispensing system features a new electric gun and advanced system software that provide automatic compensation for gluing process variables.

to the robotics industry. "I have heard some people in the industry are becoming 'chilled' right now to automation...The U.S. manufacturer is like a spoiled kid, if it (machine) doesn't work right away, he doesn't want it anymore. People have to realize that it takes 50 years to turn around an industry base. You have to invest. But there are those in the business where their only obligation is to the dollar, and if it means going overseas to make a profit—they will."

Industry Trends

The robotics industry—like the rest of the machine tool industry—is currently in an environment that is not favorable to large capital equipment expenditures. However, this has not retarded industry analysts and forecasters from predicting that the robotics industry will continue to expand at a steady clip for the rest of the century.

It is inevitible that robots will become commonplace in both large and small plants in the future. After the current growing pains of factory automation subside, robots will tie into other plant systems offering vision sensing capabilities and off-line programming, that will increase quality and productivity and at a reasonable cost.

According to a recently published 235-page study by Tech Tran Consultants, Inc., Lake Geneva, Wis., entitled, *Industrial Robots, a Summary and Forescast* "new robots appearing on the market and emerging from research laboratories are considerably more 'intelligent' than their predecessors of two or three years ago.

The study outlined the following emerging trends:

- Robots equipped with vision sensing systems are just beginning to be used in manufacturing for part sorting, inspection, guidance and control. Although the use of tactile sensors in manufacturing applications is just developing, vision sensing is available now...and is expected to be available on about 50 pct of all robots by 1995. In addition, the report noted that standardized vision modules for general use with a variety of robots will be available; real-time processing capability will be standard; image resolution will be improved; three-dimensional vision sensing will be widely available; and range (distance) sensing capabilities will be widely available.
- Force or tactile sensors are becoming commercially available...It is expected that a high resolution complaint array type of tactile sensor with a high recognition capability will be available in the near future. Force and torque sensors will also be available, for monitoring and control of operations such as drilling, routing, deburring and assembly, the report said.
- New control techniques and hardware are the next most popular areas

Justifying That Purchase Order

By Sandra Brooks
Midwest Regional Editor

One of the greatest hindrances to implementing CIM technologies has been justification; robotics is no exception.

Sales of robots and robotic equipment have fallen far short of the predicted annual growth. Penetration of new markets is slow. More than half of robotic installations are being used for automotive applications.

Yet, those companies experienced with robotic use continue to cite an increasing list of benefits directly attributable to the equipment. A list which by itself substantiates repeat orders: improved process quality, reduced setup time, increased flexibility, reduced direct labor cost, reduced quality control cost, reduced inspection cost, reduced scrap/rework, warranty cost reduction and reduced equipment cost.

Undeniably, the first attempts to apply robotics to manufacturing were complicated by the limitations of robotic technology. But, in the past five years, significant improvements have been made in robotic reliability, functionality, ease of programming, control and communications interfaces.

Still, first-timers are slow to sign a $200,000 purchase order. In most cases, the issue lies beyond the capital investment—justification gets tied-up in 'what-if' scenarios.

As with any investment, analysis and planning are key factors. The installation of even one robot could significantly impact the entire manufacturing operation. Therefore, justification must go beyond dollar amounts and managers must assess the possible effects of process automation to the manufacturing cycle.

In preparing a proposal for the application of robotic technology to a process, the existing operation, both the specific process and the organization at large, must be totally analyzed and thoroughly understood to justify the purchase of robotic equipment.

The company's manufacturing philosophy, its cost/profit targets, the goals of marketing and sales, the logistics of material in and product out, and the quality of raw materials and finished goods are but a few of the global considerations which must be taken into account when planning for automation.

On the specific process level, factors such as operator modifications to process data/equipment operation, procedures, material and informtion flow, and inventory gluts or shortages will affect, and be effected by, robotic equipment.

Assess the factors which comprise your organization and identify where changes could result in cost reductions or improved productivity and analyze why. This exercise will become your list of opportunity for process improvement.

Then cite what is needed to implement changes to the process. Analyze the impact of additional training, organizational restructuring, new process scenarios and the impact of new equipment. Don't rule out benefits which might be gained by manual processing, hard automation, automation of installed systems, process capability and design improvement or process and design innovation. Rank the various combinations of possible solutions in terms of capital investment, installation complexity, support services required and projected benefits.

Develop realistic budgets with a built-in buffer for worst-case possibilities, not only in relation to the equipment purchase but for additional training, relocation of existing equipment, line shut-down, re-design/engineering of the product, etc.

Layout a conceptual design of the equipment installation and plan for implementation. If possible, computer simulate the effects of the process back through the organization. Evaluate through-put increases quality improvements, cost reductions, reduced lead-times, lowered inventory and improved process control.

Finally, project the payback period and the long-term return on investment—shoot for a maximum of two years payback and an ROI rate of 10 to 30 pct. Include an analysis on the effect of postponing the project in terms of project cost variance next year, two years and five years out. Also take into consideration the impact of postponing automation on competitive capability, both from perceived and actual product quality/cost perspectives.

Conclude the proposal with methods by which to assess the actual benefits compared with the projected benefits at various points in the implementation, gathering data from both preproduction and production operation.

of research. These efforts range from the development of advanced control algorithms which optimize robot performance to the use of advanced computing and memory devices. These include: Use of distributed processing techniques that decentralize computing and control requirements; development of hierarchical control techniques; increased intergration of sensory data into control procedures; greater use of adaptive control techniques in processing and assembly; advanced communications and networking techniques in robotic work cells and similar integrated systems; development of control techniques for collision avoidance, multiple armed robots, and mobile robots; increasing use of the latest electronic components, including 32-bit microprocessors and other VLSI devices; and application of artificial intelligence techniques and "expert systems" for robot control and decision making.

• The major trend in programming includes the development of a new high

risk level robotic programming language and off-line systems for work cell planning, robot programming and simulation. These later techniques, in particular, the report indicated, will become commonplace in the next decade because they greatly reduce the effort and cost required to program robots, help eliminate costly errors and lead to improved work cell performance.

• Although there is some interest among robot users for the development of a standard programming language, such a standard is not likely to emerge in the near future because of the diversity of application requirements, the number of competing approaches and the rapid pace in new programming developments. One or more languages, such as GMF Robotics' 'Karel', may emerge as industry leaders, the report noted.

• Regarding systems integration, the report said that it is recognized by both robot manufacturers and users that robots are a part of integrated manufacturing systems and that robots have only limited utility as stand-alone pieces of equipment. This recognition is leading to the development of a wide variety of turn key systems for specific applications such as welding, painting, sealant dispensing, material processing and assembly. This integrated systems approach is also one of the driving forces behind the development of new sensors, interfacing and programming techniques.

In the area of mobility, robot researchers, manufacturers and users are beginning to recognize the benefits to be gained in providing some type of mobility for manipulator arms. This has naturally led to an increase in the use of large gantry-type robots and additional axes of motion, such as tracks or rails for the robot to move along. Such mobility effectively increases the work envelope of the manipulator arm and allows the robot to interface with a wider variety of equipment.

State of the Industry

Eric Mittelstadt, president of the Robotic Industries Association and president and CEO of GMF Robotics, believes that the robotics industry is going through a "natural evolution" like any other industry. "Some analysts have been saying for a long time that robotics hasn't been doing what it was supposed to do. They (analysts) were discouraged when the industry grew 30 to 35 pct instead of the 50 pct they predicted. They were unrealistic. They didn't realize that we just now are coming out of one of the worst capital equipment recessions in the past 30 years. I look at the 30 pct growth as a positive sign in that kind of economy."

Added George Munson, president Unimation, Inc.: "The industry is crowded relative to the size of the market right now. In my opinion the key issue is where the individual stands in investing in factory automation, because proliferation is tied to that. The robot is not a stand-alone device that is disconnected from other technologies. So much depends on how the individual invests in factory automation.

The Best of the West

The top four robot manufacturers in the United States are GMF Robotics, Cincinnati Milacron, Unimation and ASEA Inc.

• GMF Robotics: Less than four years old, GMF Robotics is the largest full-service supplier of robots in the United States with 1985 sales around $187 million.

Formed through a joint venture between General Motors and Fanuc of Japan, GMF quickly rose to the top supplying robots to the automotive industry, the major end user of robotics.

GMF holds about a 30 pct share of the U.S. market. The company manufactures assembly, gantry, spray painting and material handling robots. In addition, GMF sells process robots for arc welding, waterjet cutting, sealing and deburring applications.

Although GMF is mostly noted for its sales to the automotive industry, the company has sold robotics to about 630 customers, of which less than 10 pct were automotive related. Of course most of GMF's volume sales are to the automotive industry, but the company is striving to increase its sales to non-automotive industries.

• Cincinnati Milacron: One of the early leaders in the industry, is second to GMF, with 1985 sales estimated to be more than $50 million.

A full-service company, Cincinnati Milacron offers gantry, articulated and cylindrical coordinate robots. The company, also a major supplier to the automotive industry, is branching out into other markets such as aerospace and batch processing.

• Unimation: Considered to be the pioneer in robotics, has a 9 pct share of the market, according to 1985 statistics, with sales estimated at close to $50 million.

The company, purchased by Westinghouse in 1983 from Condec Corp., offers assembly robots; robots for material handling, welding, drilling and sealing applications. Unimation also offers its VAL programming and control language.

• ASEA-USA, Inc., A subsidiary of ASEA AB of Sweden, holds around 10 pct of the current U.S. market with 1985 sales estimated at around $40 million. However, worldwide, ASEA earned $120 million in sales and is one of the leading international robotics companies.

The company specializes in articulated arm robots that are used for welding, spraying applications, deburring and polishing. The company has sold approximately 5,000 robots worldwide.

ASEA also offers robotic support systems such as controllers, sensors, programming packages, and grippers.

Other robotic manufacturers worth noting include Adept Technology, DeVilbiss, American Cimflex, General Electric, U.S. Robots, ESAB, Prab and Panasonic.

Both Mr. Mittelstadt and Mr. Munson and other industry officials interviewed by PRODUCTION Magazine agree that there will be a "shake out in the number of robotics manufacturers within the next five to 10 years.

The industry is currently in a period of what some call "sustained growth." Close to 30 companies have already exited the market leaving about 70 manufacturers.

"There aren't as many robot companies as some people think," said Laura Conigliaro, a Prudential Bache Securities analyst and long-time observer of the industry. "It (number of manufactuers) will get smaller, not because companies will get pushed out, but because some companies won't be able to reach the masses to justify staying on.

Ms. Conigliaro asserted that the industry has some "real problems." She said that growth is very slow this year, about 5 pct over 1985 and the industry is a very "solutions-based" oriented industry right now. "Robots are hard to get installed and we're not in a good (economic) environment...it is affecting all capital equipment," she noted.

James Coshnitzke, manager of marketing and communications at Cincinnati Milacron, observed that he sees very few changes in the next three to four years in the industry. Mr. Coshnitzke said that the industry is moving towards off-line programming, vision and concentrating on penetrating other markets. "There will be a lot less R&D devoted to hardware," he said.

"The evolution will be in sensors and vision," said Brian Carlisle, president of Adept Technology, Inc. "Adept will concentrate producing generic products that have high performance capabilities. The evolution is in vision to simplify automated storage and retrieval, material handling and parts picking."

"I'm hesitant to say we should stop developing hardware," commented Mr. Mittelstadt. "It only takes one company to implement a new vision system or come up with a new manipulator that could put us all out of business. Technological advances have to be cost justified. We have to realize that the reason there are more robots in Japan than anywhere else is that they keep them simple. We don't understand that in the U.S. We tend to buy more technology than we need at times. Yes, we need complex robots for complex jobs and simple robots for simple jobs ...then the cost will be justified." P

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